BELLCOMM, INC.

SUBJECT: Radiation Doses in Lunar Orbit
Case 232

DATE: May 23, 1967

FROM: R.H. Hilberg

ABSTRACT

Long duration manned missions in lunar orbit are subject to the significant probability of the occurrence of a solar cosmic ray event. The importance of such events to a lunar orbit mission of 35 days overall duration, 28 in lunar orbit, is discussed in this memorandum. It is estimated that with 99.9% reliability solar cosmic rays will present no hazard to the astronauts, although the possibility exists that mission modifications may be desirable.

(NASA-CR-154913) RADIATION DOSES IN LUNAR ORBIT (Bellcomm, Inc.) 7 p

N79-73453

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MEMORANDUM FOR FILE

Long duration manned missions in lunar orbit will be exposed to the possible occurrence of severe solar cosmic radiation. The extent to which such radiation may be harmful to the astronauts is discussed in this memorandum. Since the problem of solar cosmic radiation is much less severe during the minimum of the cycle of solar activity than during the maximum, only the period of high activity will be treated. The particular mission examined is a mission of 28 day lunar stay time, and 7 day total transit time. The lunar orbit was taken to be circular, with an altitude of 80 nm above the surface of the moon.

FLUX MODEL

The particle flux values and spectral shape used for the calculations are those of Webber (Ref. 1). The dose calculations are those of Shipley (Ref. 2). The shield used is that of the early NAA description of the CM. Since that time, the CM shielding model has been modified in such a way as to reduce the dose by about 10%. The effective shielding of the moon has been included in the dose calculations for the lunar orbital phase of the mission. This reduces the dose to about 70% of the free space dose. It has been implicitly assumed that the particle flux is isotropic.

DOSE LIMITS

Two dose limits have been established by the MSC Medical Office: a Planning Operational Dose (POD), and a Maximum Operational Dose (MOD). The skin MOD is defined to be that dose which produces erythema in 10% of the people exposed, while the depth MOD is that dose which causes nausea in 10% of the people exposed. The PODs are defined as half of the MODs. Reference 3 gives the dose limits given in Table 1. Note the inconsistency between the cabin skin POD and MOD and the definition.

Some films are considerably more sensitive than man. Therefore, doses that may not be dangerous to the astronauts may affect the success of some photographic mission objectives.

TABLE 1

	MOD	POD
Skin Dose	400 rad	250 rad
Gastrointestinal Tract	50 rad	25 rad

CALCULATIONS

Skin doses and 4 cm depth doses are calculated for an astronaut inside the CM. Both the free space doses and the lunar orbit dose probabilities were calculated for 7 and 28 days, respectively. The dose probability values were estimated by calculating the dose resulting from each event of the 19th solar cycle and combining this dose distribution with a uniform event occurrence probability for the maximum of the solar cycle. If the number of events of the 19th solar cycle for which the dose exceeded D_o is expressed by $N(D > D_o)$ and the total number of events for the 6 year maximum is N_o then $P(> D_o)$ =

$$\left(\frac{N(D > D_o)}{N_o}\right)\left(\frac{N_o}{t_{solar\ max}}\right) t_{mission} = N(D > D_o) \left(\frac{t_{mission}}{t_{solar\ max}}\right)$$

The resulting values for the probability of exceeding the 4 cm MOD and POD for the two phases of the mission are given in Table 2. For no event did the skin dose exceed the skin POD, so this particular problem will not be discussed further.

TABLE 2

PROBABILITY OF EXCEEDING DEPTH DOSE LIMITS

	7 Days in Free Space	28 Days in Lunar Orbit
MOD	.4%	.9%
POD	.8%	2%

If crew safety is desired to be at least 99.9%, and one defines crew safety with respect to the symptoms used in evaluating the MOD and POD limits, then one should assign a goal of about 1% for the probability of exceeding the MOD. In the case of depth doses, this limit is 50 rad. Table 2 indicates that the probability of exceeding the MOD is about 1%, so that solar cosmic radiation should not be an important constraint on the mission. However, the probability of exceeding the POD, and therefore requiring some type of mission modification, possibly affecting mission success, is several times greater.

DISCUSSION

Because of the long transit time from the moon to the earth there is little or no benefit to be gained from aborting a mission as soon as particles are observed, as far as the dose from a particular event is concerned. In fact, remaining in lunar orbit may be helpful because of the shielding provided by the moon. However, because of the likelihood that one large proton event will be followed by another within a week, some type of abort may be desirable.

The dose acquired may be reduced somewhat by taking into account the fact that most of the dose is produced by protons penetrating a few relatively thin parts of the spacecraft. These parts can be pointed toward the moon, thus reducing the dose more than just the 30% reduction caused by the moon.

The warning system now envisioned for Apollo, and which would be helpful for a landing mission, would not be particularly helpful for this type of mission. In order to be useful a reliable system giving about 3 days or more forecast would be essential. Such a system does not seem likely in the near future.

CONCLUSIONS

The reliability of not exceeding the established dose limits seems low enough that there will probably be insufficient justification for spending great efforts to reduce it further. Reducing the dose significantly can only be done for this type of mission by rather difficult means. Because of the reasonable shielding provided by the CM, reducing the dose by further shielding would require sizeable added weights (about 4 g/cm^2 to reduce the dose by another factor of 2). A long development program would be necessary to provide a useful forecasting system. Thus there seems little that can be done to improve on the situation, which is actually not particularly bad to start with.

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2. E.N. Shipley, "Radiation Dose Calculations"Bellcomm TM-64-1012-2, (July 15, 1964).

3. D. Owen Coons, "Radiation Dose Levels for Apollo Crew Members, AS-503" Memorandum from DD/Medical Operations Office to FA/Technical Assistant for Apollo (March 1, 1967).

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